Assimilation of AIRS data with Local Ensemble Transform Kalman Filter

PROGRESS REPORT

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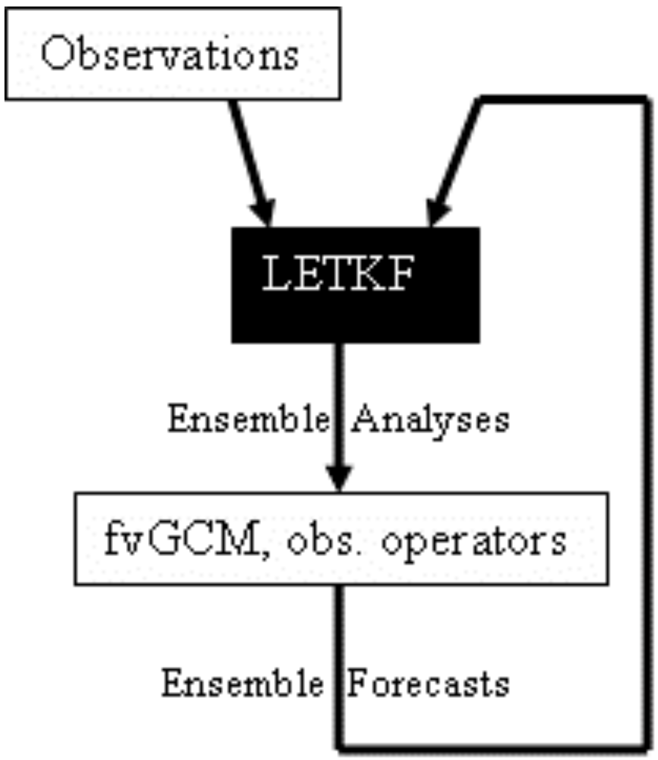
Outline

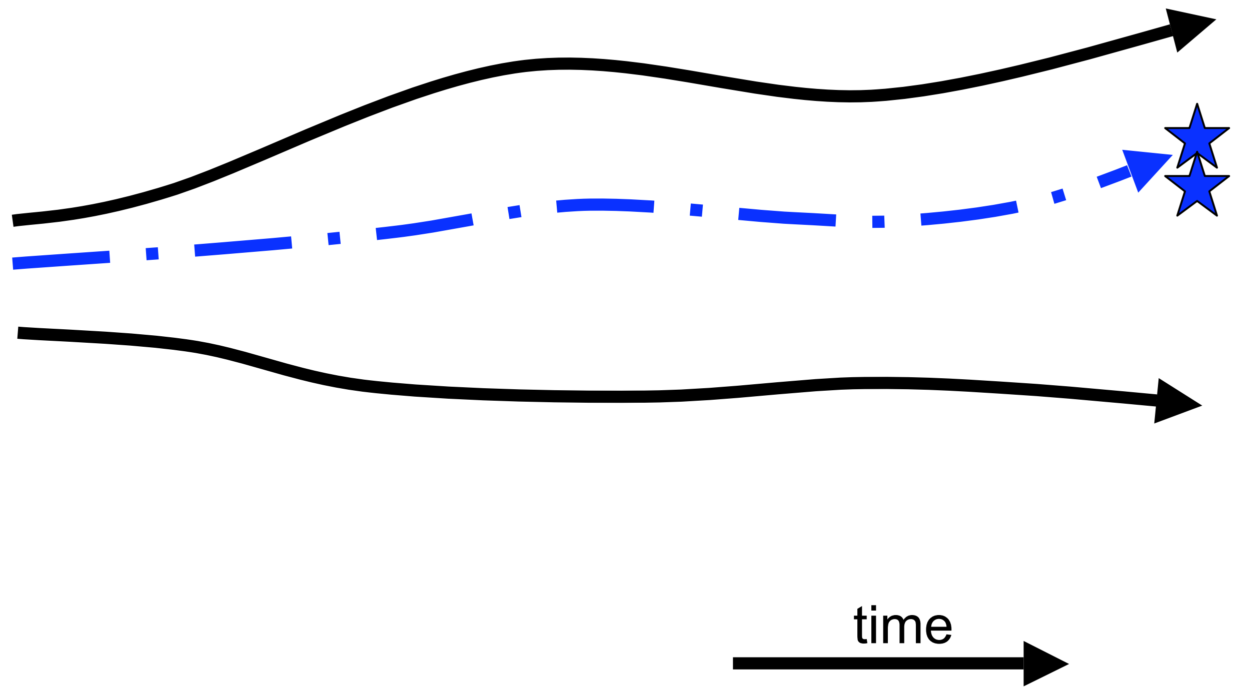
- Background
  - 3D-LETKF and its 4D-LETKF extension
- Previous Results
  - Advantage of 3D-LETKF over PSAS with simulated data on NASA GEOS-4
  - Szunyogh et al. assimilated non-radiance observations with 4D-LETKF on NCEP GFS
- Current Results
  - Found large improvements by adding AIRS retrievals!
  - Adapted CRTM for LETKF on the NCEP GFS
- Planned Experiments
  - Optimize assimilation of AIRS retrievals (correlated errors)
  - Assimilate AIRS clear radiances
  - Assimilate AIRS cloud-cleared radiances

Summary of LETKF

- Matrix computations are done in a very low-dimensional space: both accurate and efficient, needs small ensemble.
- The analysis is computed independently at each grid point, highly parallel!
- Very fast! 5 minutes in a 20 PC cluster with 40 ensemble members.
- Model independent, does not require adjoint of the model or the obs. operator.
- It knows about the "errors of the day" through P^f.



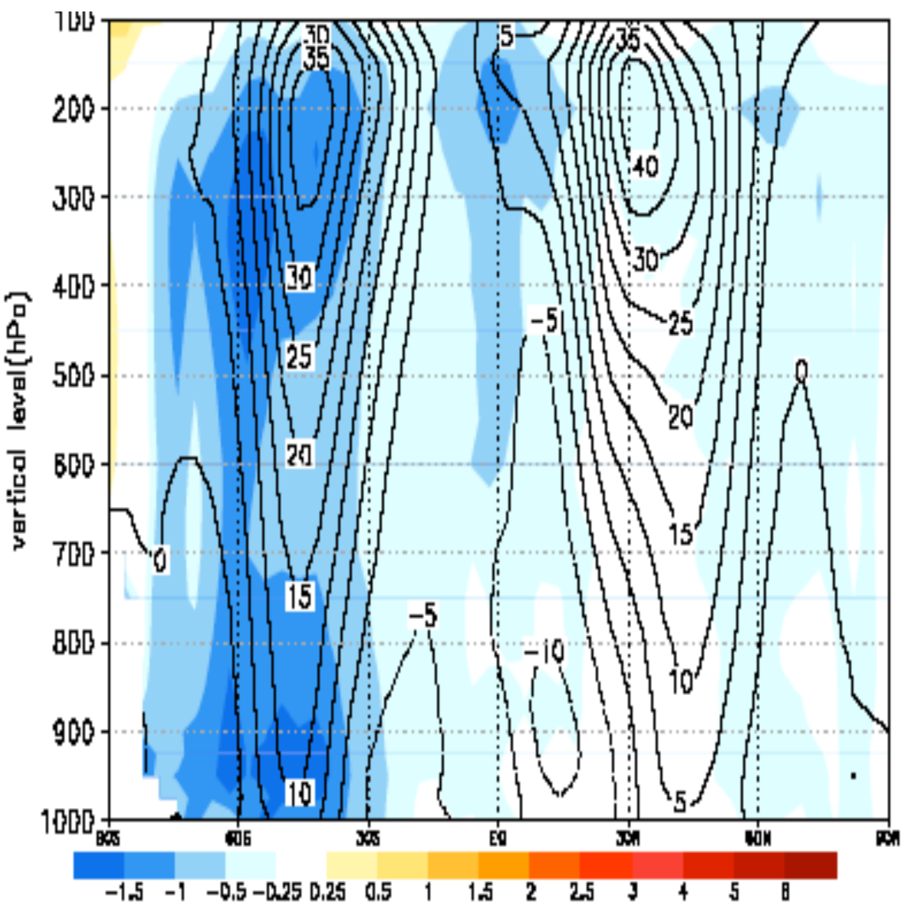
3D-LETKF (used before)



3D-LETKF finds the best linear combination of the ensemble members fitting the observations at the analysis time

3D-LETKF VS. PSAS with simulated Rawinsonde data on NASA GEOS-4

Zonal Wind

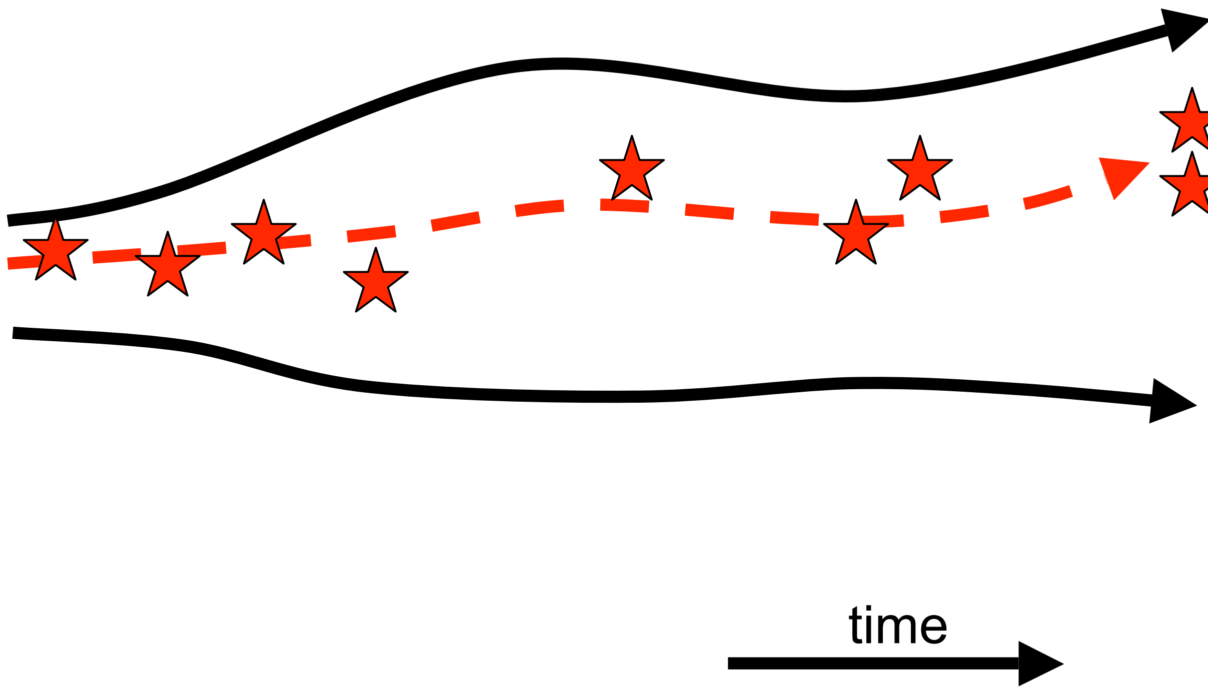


Blue means LETKF better than PSAS

RMS (LETKF) – RMS(PSAS)

- With simulated observations, 3D-LETKF is much better than PSAS everywhere except at the south pole.
- We are now using 4D-LETKF with the NCEP GFS model, and real observations.
- Szunyogh et al (2006) assimilated all operational non-radiance observations.
- We now added Chris Barnet’s AIRS temperature retrievals.

4D-LETKF
(better for continuous sat data)



4D-LETKF finds the best linear combination of the ensemble trajectories fitting the observations within the analysis window

4D-LETKF vs. SSI on NCEP GFS

NCEP GFS: T62 Resolution, 28 Vertical levels.

Observations: All operational observations except for radiances (Non-radiance hereafter)

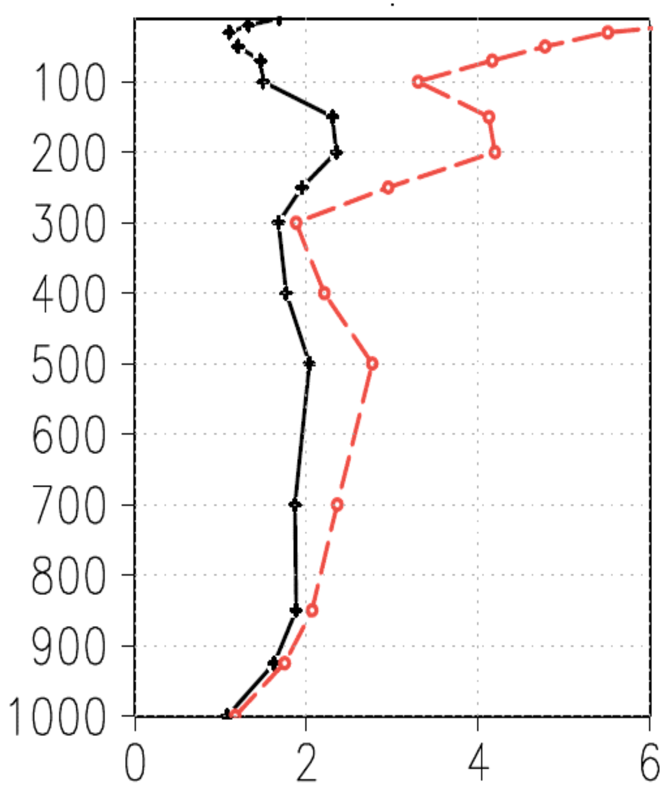
Verification: Operational NCEP analysis at T254L64, assimilating all operational observations.

Szunyogh, Kostelich, et al. showed LETKF better than SSI

Comparison of 4D-LETKF and SSI assimilating all non-radiances in NCEP GFS (Szunyogh et al)

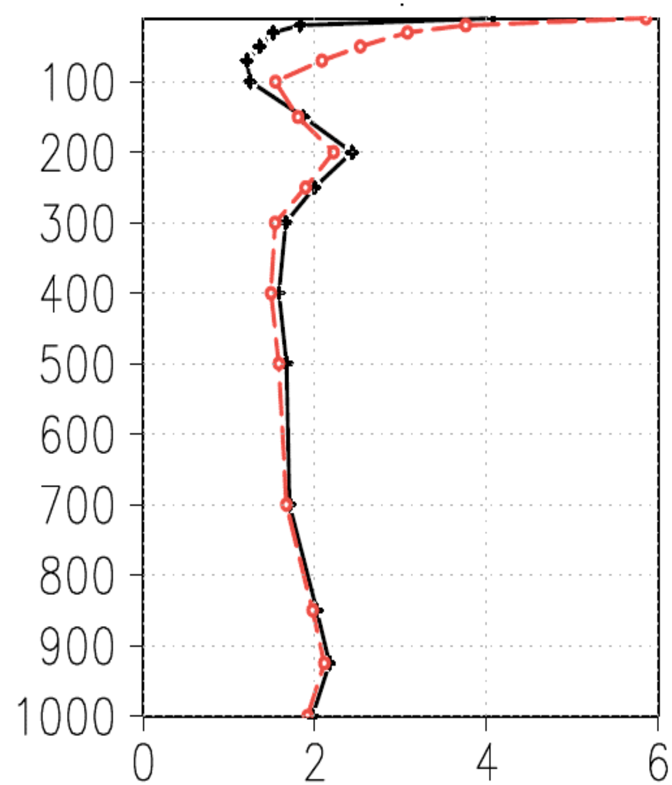
Temperature (48hr)

SH



In SH, the LETKF results are much better than SSI

NH



In NH, the results are comparable

Assimilating AIRS data

Data Assimilation of AIRS retrievals on NCEP GFS with 4D-LETKF

Control Run: Non-radiance data (Szunyogh, Kostelich, et al.).

AIRS Run:

Non-radiance plus AIRS temperature retrievals provided by Chris Barnet (NOAA)

v5 emulation with "qual_temp_mid=0"

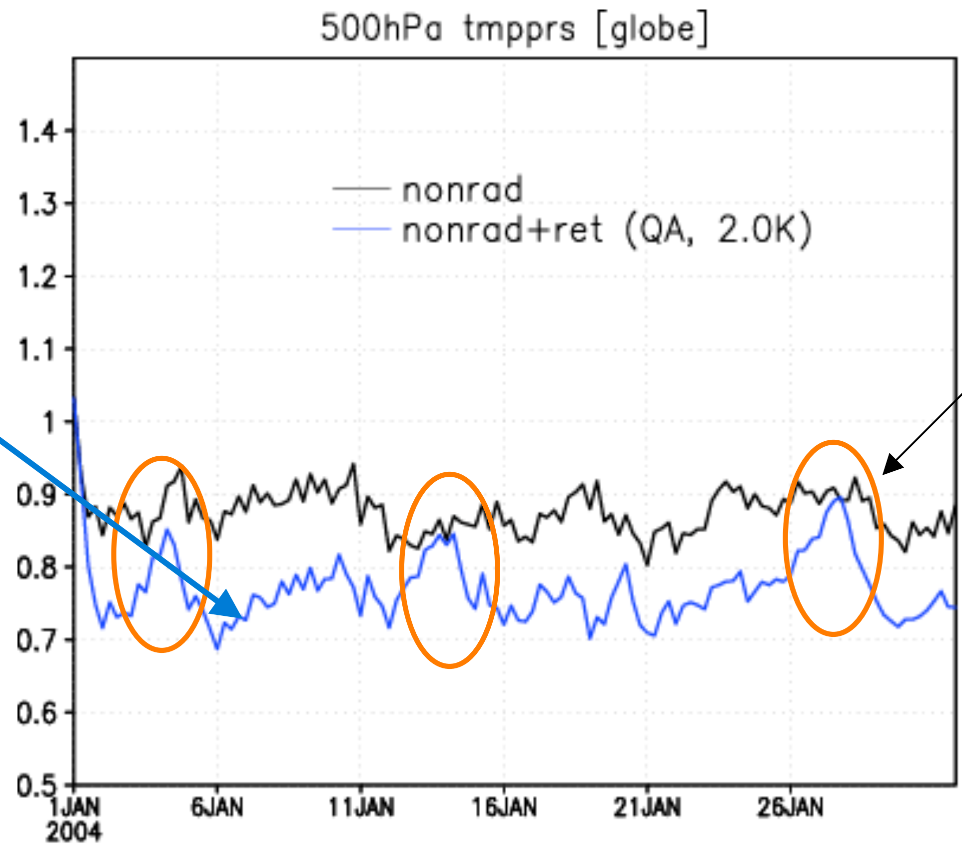
Assumed observation errors are 2 K and ignored retrieval error correlations.

Verification: Operational NCEP analysis at T254L64, assimilating all operational observations. (Not "truth"!).

AIRS temperature retrievals have a significant impact.

500 hPa Temperature analysis error averaged over Globe

Consistent reduction of errors with AIRS retrievals!

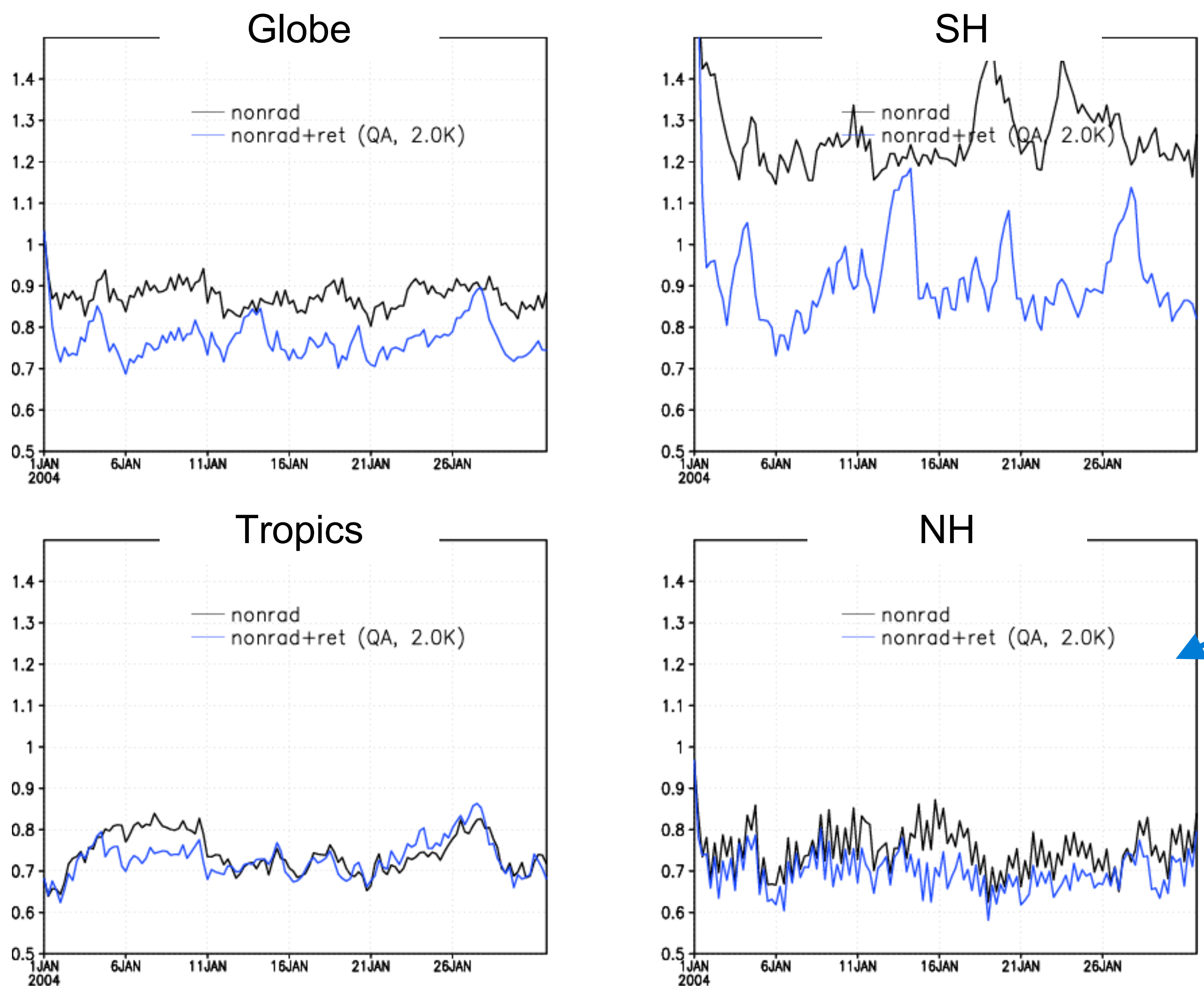


No AIRS retrievals

Non-radiance Non-radiance+temperature retrieval (QA)

Result are similar to non-radiance when there are no available retrievals

500 hPa Temperature analysis error

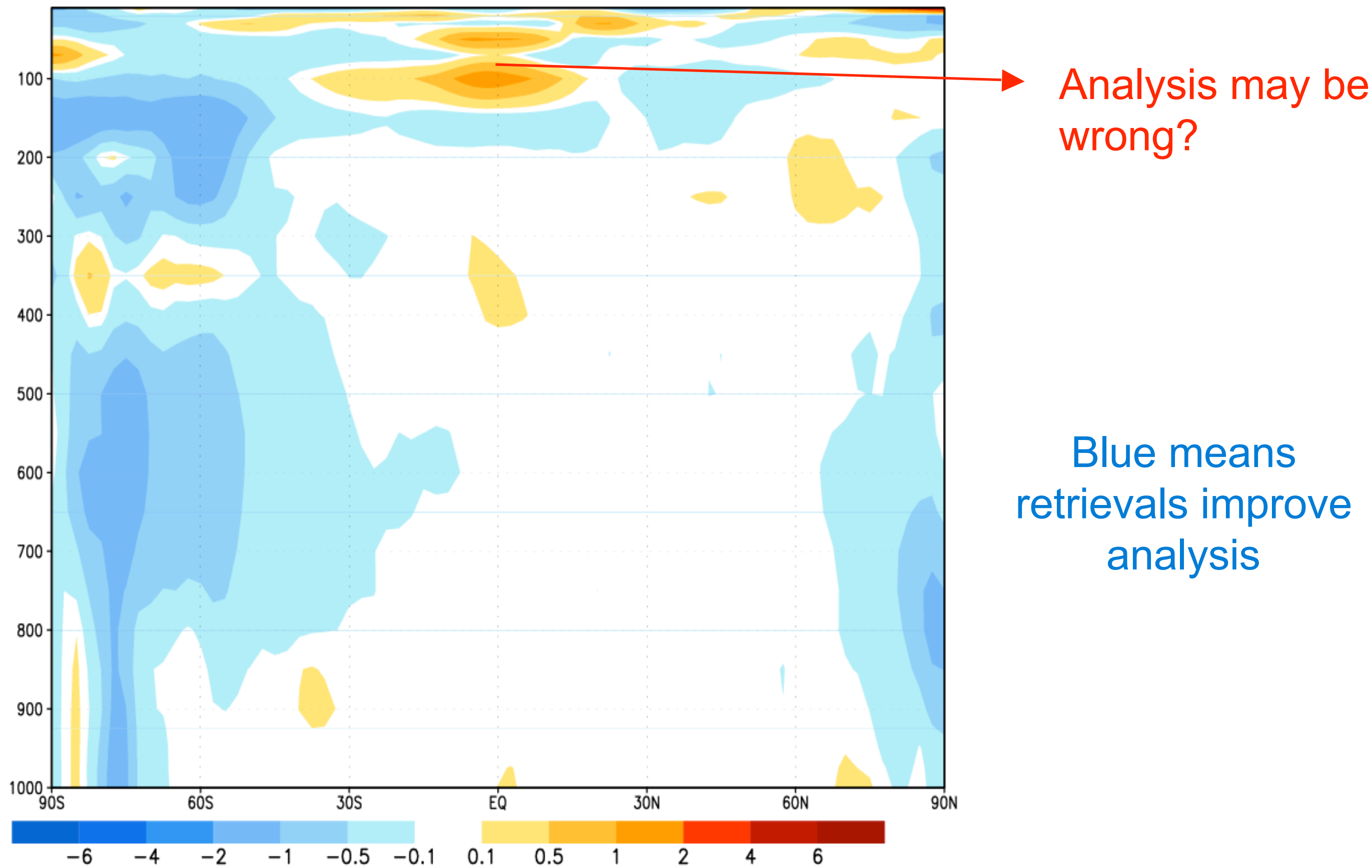


Consistent positive impacts even in the NH!

Non-radiance   Non-radiance+temperature retrieval (QA)

Zonal Average temperature analysis error

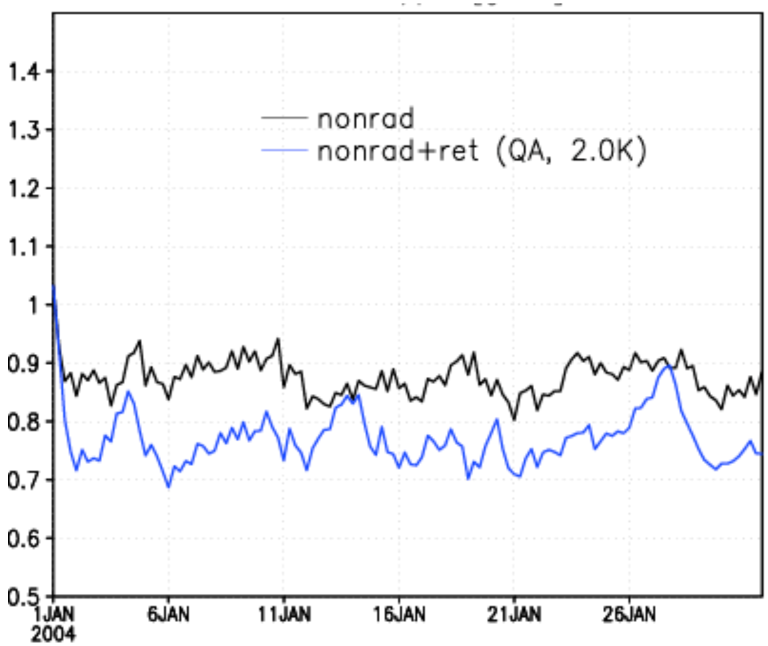
RMS (non-radiance + retrievals) – RMS (non-radiance)



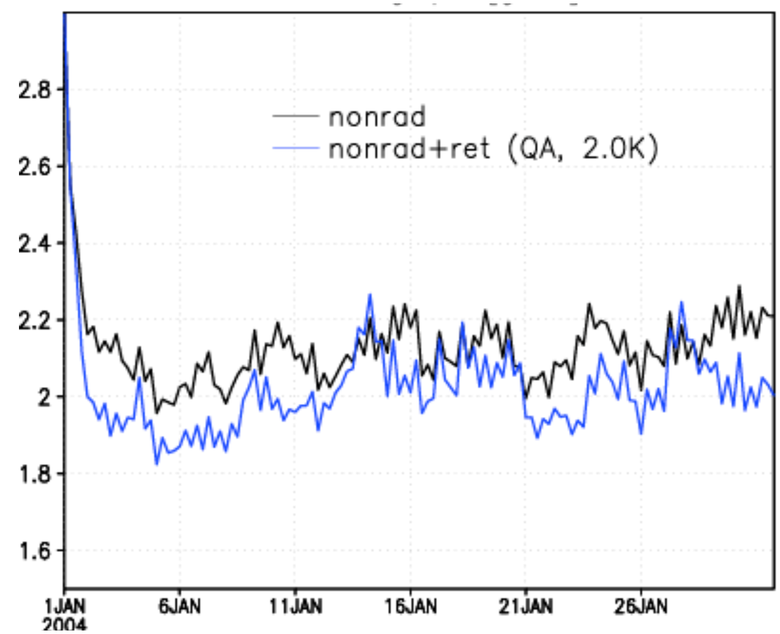
AIRS Temperature retrievals have positive impact in both NH and SH, and little impact on tropics.

Impact of AIRS Temperature retrievals on zonal wind

500 hPa Temperature

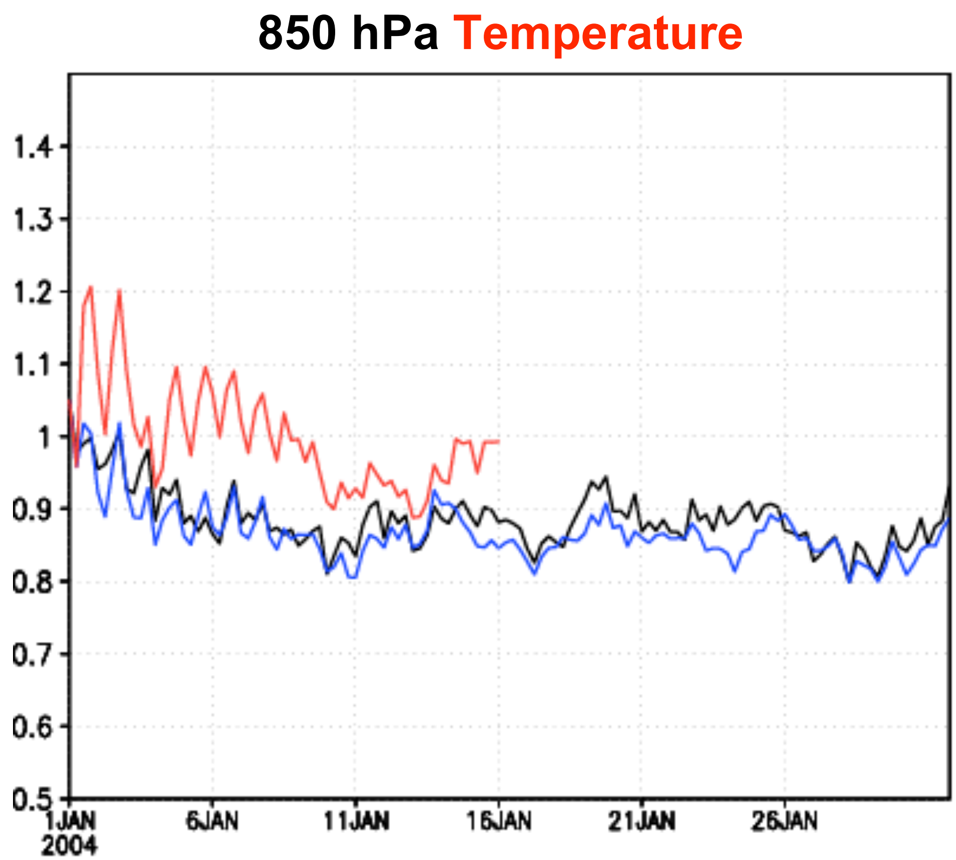


500 hPa zonal wind



AIRS Temperature retrievals also have positive impact on other variables

Impact of Quality Control on analysis



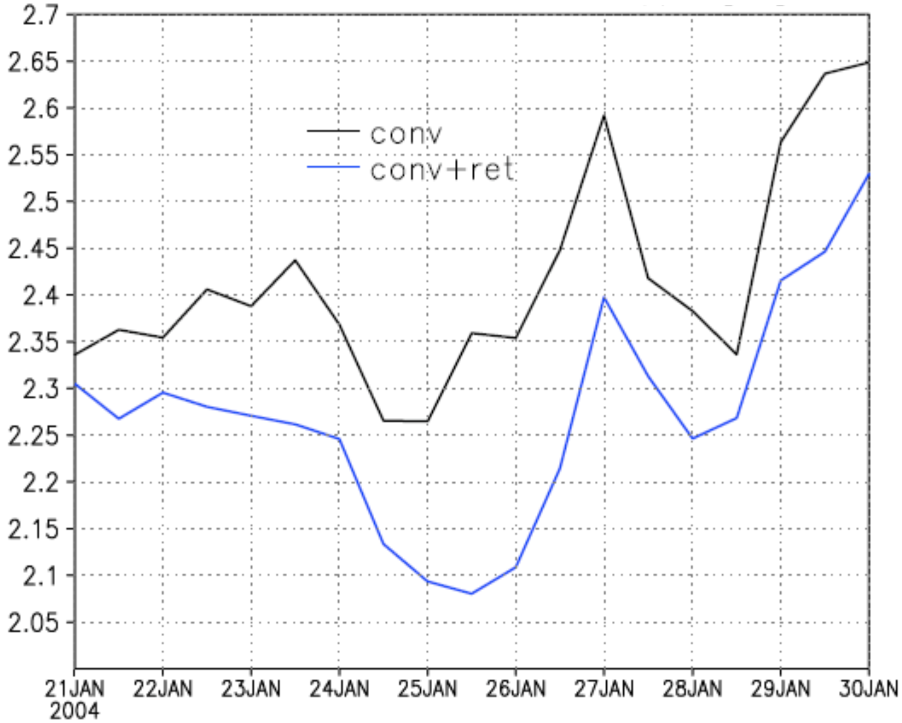
Non-radiance+temperature retrieval (without QA)

Non-radiance Non-radiance+temperature retrieval (QA)

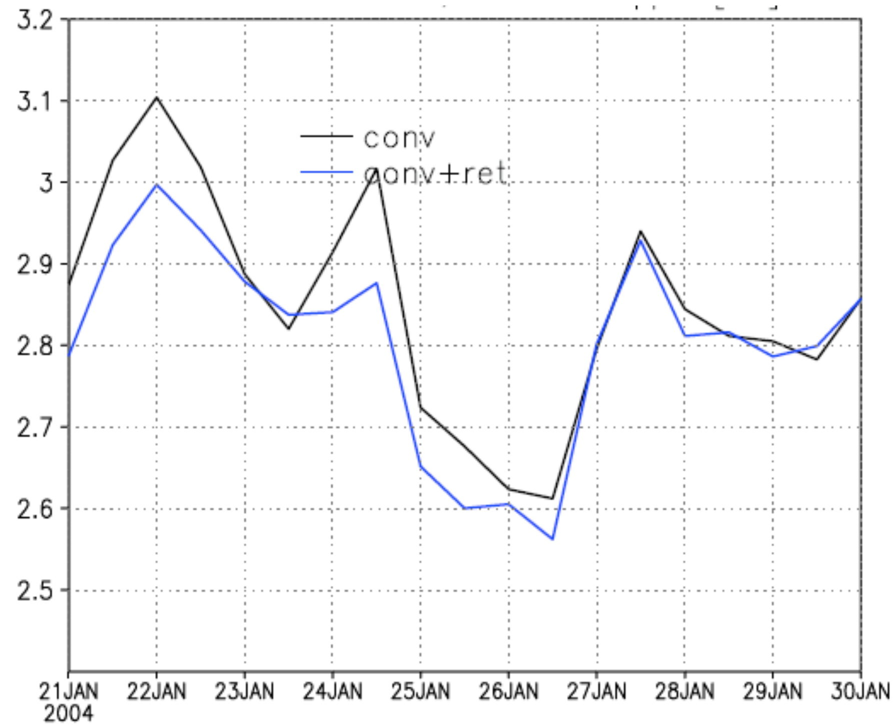
Quality control makes the results significantly better

48 Hour Forecast

500 hPa Temperature (SH)



500 hPa Temperature (NH)

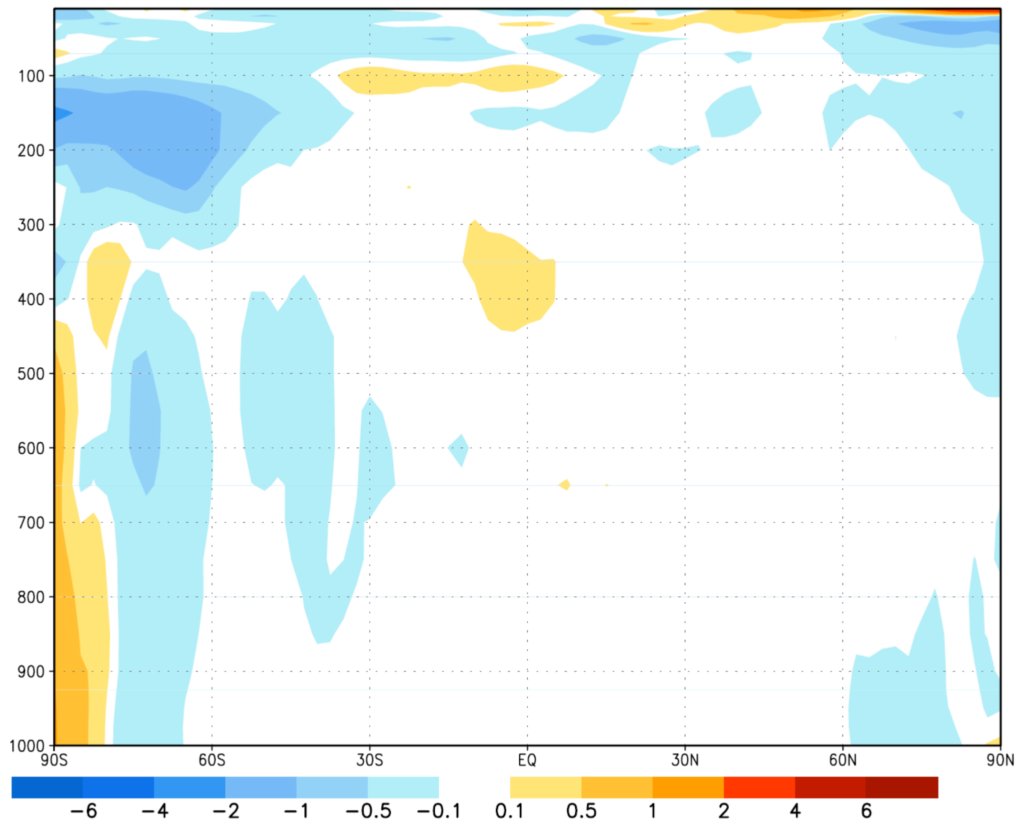


Non-radiance Non-radiance+temperature retrieval (QA)

48 hour forecasts retain the advantage of assimilating AIRS Temperature retrievals.

Zonal Average temperature 48 hour forecast error

RMS (non-radiance + retrievals) – RMS (non-radiance)



Blue means retrievals improve forecast

AIRS Temperature retrievals have positive impact in both NH and SH, and little impact on tropics.

Conclusions

- LETKF is an efficient and parallel method of data assimilation. 5 minutes in a 20 PC cluster with 40 ensemble members.

- LETKF can use the nonlinear observation operator and does not require Jacobian or the adjoint. We can compare different nonlinear forward operators.

- LETKF provides a better analysis than the operational 3D-VAR scheme with real observations excluding radiances.

- Observed significant improvement from assimilating AIRS temperature retrievals. Above 100mb the operational analysis may be wrong or be biased.

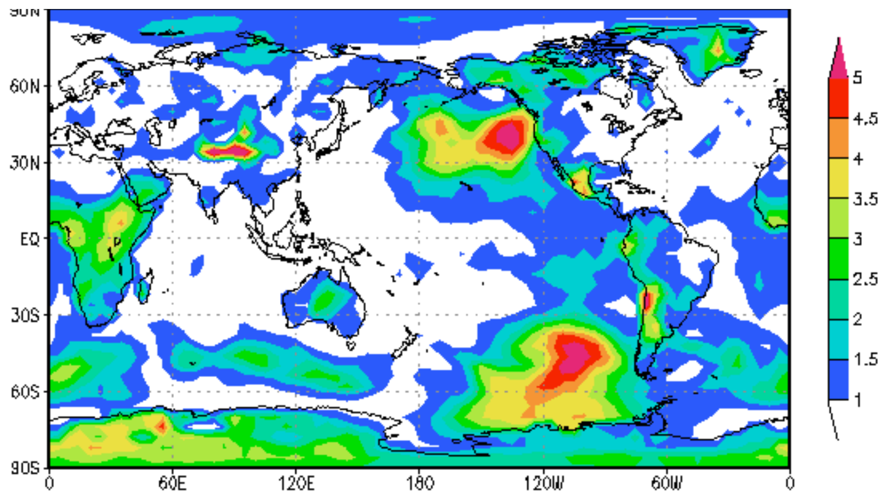
- AIRS quality control makes the result better.

Preparation for assimilating AIRS radiance

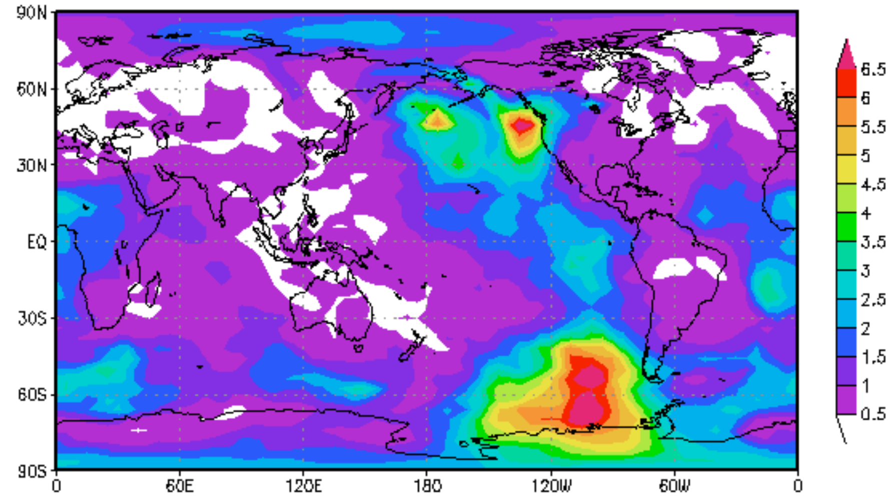
- Adapted CRTM for AIRS radiances to work with both NASA fvGCM and NCEP GFS model.
- We will apply 4D-LETKF with the NCEP GFS model, and assimilate simulated AIRS radiances.
- From perfect model experiments with the NASA model, expect a significant impact of AIRS radiances.

Potential Impact of AIRS Radiances

Background Ensemble Spread: AIRS channel 232



Background Ensemble Spread: Temperature (500 hPa)



Ensemble spread in AIRS radiance matches the ensemble spread in temperature.

Assimilating AIRS radiances with LETKF should improve temperature analyses.

Planned Experiments (Retrievals)

1) *Tune AIRS temperature retrievals:* optimize observation error covariance for AIRS retrievals using a new adaptive technique based on Miyoshi and Kalnay (2005) and Desroziers et al. (2006).

2) *Include AIRS humidity retrievals:* Will provide dense and accurate information for the humidity. Need to adapt LETKF to assimilate humidity accurately.

Planned Experiments (Radiances)

1) Assimilate clear AIRS radiances: They are very accurate but are very sparse.
(Since we do not require the Jacobian and adjoint, we could use L. Strow's observation operator)

2) Assimilate cloud cleared AIRS radiances: Abundant as the retrievals but with simpler observation errors

3) AIRS data impact: Compare analyses and forecasts to estimate the impact of AIRS alone.

Planned Experiments

We would appreciate your advice regarding these experiments!!!!!

References and thanks:

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Local Ensemble Transform Kalman Filter

Perform Data Assimilation in local patch (3D-window)

- The state estimate is updated at the central grid red dot

- All observations (purple diamonds) within the local region are assimilated